The crop of 1910 was not raised without labor, anxiety, and loss. The loss was doubtless more than it should have been. Whoever contributes to reducing the loss performs a work of value, we hold, not only to the fruit grower but to all mankind.

In past years there were certain losses due to what may be called natural causes, which were considered by fruit growers and fruit consumers as beyond the power of the grower to prevent. But of late, largely through the directive knowledge of the experts of the Department of Agriculture and the ready acceptance of their work by the growers and shippers, losses have been minimized or greatly decreased.

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Passing over problems of loss due to high winds, or injury caused by drought on the one hand or excessive moisture on the other, also unfavorable weather at critical times, such, for example, as the warm spells during September in the apple belt of California, and all the losses connected with low temperatures experienced by packed fruit while in transit, we come to one source of loss which in its way perhaps has caused greater damage than any other one condition, namely, frost.

It is a constantly recurring source of danger. It is quick in action, for the work of a year with its hoped-for profits may be made valueless in a single night by frost. It is a complicated problem, calling for a knowledge not only of the plant and its condition but a somewhat detailed knowledge of the physics of the lower air and especially the method by which heat is gained, retained, or lost by plant surfaces. In many respects our knowledge of these conditions is quite imperfect and we are working in the dark. Instruments of sufficient sensitiveness are not available, or at least have not been used, to get a complete and continuous record of the changes going on near the plant surface during cold winter nights and frosty spring mornings. Nor are the problems connected with the condensation of the water vapor and the formation of the frost crystals altogether simple. Indeed, the formation of what is called frost, i. e., the crystals of ice, is really preventive, heat being given off in the solidification. Furthermore, at a later period, when, under the influence of the heat of sunrise, the frost crystals melt, heat is required, and to some degree this prevents a too rapid warming up; and still further, when the frost has changed to water, there is still to be considered the latent heat of vaporization. This latter amount is, in round numbers, about 600 calories and the former quantity, or the latent heat of fusion of ice, about 80 calories.

In its efforts to devise adequate methods of protection against frost the Weather Bureau has for a period now extending over 15 years studied the problem from two viewpoints, and it can be said that a high degree of success has resulted. The first phase of the problem naturally would be the giving of accurate warnings of impending low temperature. This is not an easy matter, and at the beginning of the frost campaign the forecasts were somewhat uncertain. Persistent effort and constant vigilance have brought their reward, and I know it will please this body of practical men to hear that during the winter of 1909–10 in California there was not a single forecast of injurious frost that was not fully verified, and, what is still more satisfactory, there was not a single frost injurious to fruit occurring during that period that was not forecast from 12 to 36 hours in advance. In other parts of the United States this problem of forecasting frost is being rapidly developed and it seems likely that an equally high efficiency will be attained.

The second line of action in connection with the protection of fruit from frost was to develop adequate ways and means for controlling the temperature. Taking the problem broadly, two plans of action presented themselves: First, the plant itself was to be so selected, bred, and developed as to offer as far as possible the needed resistance to the low temperature; or, what is practically the same thing, to render the plant dormant and not sensitive during the cold period. The other plan of action was to fight the cold and minimize exposure thereto by producing heat artificially during the cold period.

Under the first plan there has been some work done in producing a resistant stock; but in California, chiefly owing to the fact that extreme low temperatures seldom occur and are of short duration, attention has been given mostly to the second method—i. e., preventing too great a fall in temperature and a too rapid rise in temperature after the plant tissue has been chilled. There are a number of ways in which this can be done, but the simplest method is to add heat to the lower air at the critical time to keep the plant and fruit warm. This is best done by burning fuel in various ways, either in a number of small fires, such as coal baskets, oil pots, orchard heaters, or small open fires. Within the last three years convenient forms of orchard heaters have been devised, some burning coal and others burning oil. These are now in widespread use and have been successfully used in raising the temperature 5° or even more at critical times and have demonstrated their worth beyond future question. They have many advantages, and if the expense is regarded in the light of an insurance premium the results have been most satisfactory from a financial standpoint.

Whether the actual use of fuel and combustion methods are the most economical of possible methods is an open question. It should have been stated that large fires are neither economical nor efficient, and the heat energy is largely misapplied and practically wasted so far as the orchardist is concerned. With smaller fires, well distributed, there is less of this heating up of all out-of-doors, as it has been called, and a more economical use of the fuel. Indeed, competition between the various makes of orchard heaters now on the market is keen in this matter of getting the best combustion and the highest efficiency.

There are, however, other ways of obtaining heat, or rather utilizing natural conditions, and possibly in these will be found the ultimate frost protector of highest efficiency and lowest initial cost, as well as cost of maintenance. If by any means we can conserve the heat of the afternoon hours, expending it gradually during the night hours and not at an extravagant rate, as is the case normally, we will be using the cheapest and cleanest of all fuels. One way to do this is to use a cover, trapping the earth heat and permitting a slow escape between the hours of midnight and sunrise. The plants themselves may be covered, which is an old, old method of protecting against frost; but the labor item and the time required militate against this practice on a large scale. Long rolls of prepared cloth, paper, or burlap may be spread over the ground in the orchard about 3 o'clock in the afternoon. The ground under cover thus remains at a comparatively high temperature. About midnight or some time thereafter the material may be rolled up and easily removed. It is also advisable that sand or loose earth be dusted over the cover or spread to a light depth. This is easily displaced in the process of rolling up the lengths of cover by simply shaking these. This process secures a large amount of earth heat, i. e., second-hand sun heat, and sets it free at a time when the temperature is falling. In most cases the supply of heat will be sufficient to prevent critical temperatures before sunrise. It should also be pointed out that a small amount of dust in the lower air serves to prevent the usual rapid rate of loss by radiation. In fact, a certain amount of heat is reradiated. It is also possible, although as yet experimental evidence does not fully demonstrate this, that slow convectional currents prevail in the lower air and the heat is thus more uniformly distributed.

Another way is to employ some substance having, like water, a high specific heat and allow it to give up this heat slowly. In California experiments have been made with heated water, and there is no question about the efficiency and cleanliness of the method. The expense has been the chief obstacle to its widespread introduction.

Recent work by Weather Bureau officials in connection with the cranberry bogs of Wisconsin has brought out the fact that the condition of the soil with regard to what may be called cumulative low temperatures plays an important part. The ground being cold, frosts occur in the marshes in May and early in June when the temperature of the air would not of itself cause frost. By cleaning, draining, and sanding damage by frost has been prevented. There was found to be a close relation between daily maximum air temperature and soil temperature and also a close relation between soil temperature and the ensuing minimum. It must, however, be remarked that similar climatic conditions do not prevail in California, and other methods are more appropriate. If we use some good absorber of heat and can in any way conserve this heat, we have a longer period of comparative warmth and also can heat the lower air by conduction or convection. A good radiator loses heat rapidly on quiet, clear nights, and the radiant heat does not warm the fruit.

Finally, there is the method of mixing or stirring the air, which has not yet been utilized on a commercial scale. Frost is largely a problem of air drainage. As a result of many experiments it is found that where there is a mixing of the air strata or where there is good ventilation there is less frost than where the air is quiet and stagnant. Every one is familiar with the fact that frost does not occur on windy nights, which in a measure is the result of dryness, but also partly due to the fact that the layers of air are thoroughly mixed and whatever heat may exist at a moderate height above the ground is not confined to that height.

Finally, the most successful frost protection may be a combination of the various devices now in use and others based upon the principles mentioned above.

STRAW AS PROTECTION AGAINST FROST.

By ALEXANDER G. MCADIE.

The writer was recently appealed to for an opinion as to whether a covering of straw would provide an effective protection for young oats under it against injury by frost. The answer was that straw spread over the ground and used as a cover would certainly protect. It appeared later that there was another possible source of injury in the discoloration of the oats, which were found to be so injured under the straw mulch. Moreover, it was found that the straw had not been freshly spread, but remained in place for quite a time. The problem therefore becomes a different one, for we are no longer dealing with the original soil and its capacity to absorb heat, accumulate the same and also radiate it, but with a new condition and practically a new top soil. Straw is an excellent radiator and would cool rapidly at night. Moreover, the soil beneath is screened from full insolation and acquires only a partial quantity of the heat it would receive if uncovered.

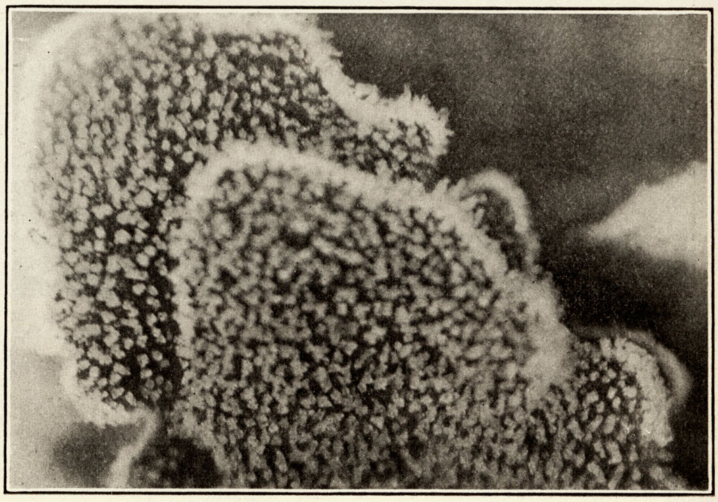
It was pointed out that to get the best protective effect the straw should be spread daily, preferably about 4 p. m. or a little before sunset, and removed about sunrise or just before.

It was also pointed out that the copious deposit of frost upon the straw, claimed by one party in the controversy to prove the existence of low temperature, did not necessarily measure the degree of fall in temperature. In fact, a heavy deposit was evidence rather of much water vapor present near the ground or on the surface of the straw. Estimating temperature fall by the amount of frost formed may lead to error. A rotten board, a manure heap, or, as in this case, old straw more or less damp absorbs moisture and holds it. If the substance is a good radiator, there is a quick cooling and any moisture near by will quickly condense on the chilled surface. The moisture may come from the ground or from the substance or may be in the form of vapor in the lowest air layer. Materials having a lower moisture content, although in proximity and similarly exposed, will show less frost; i. e., the condensation will be nothing like as heavy on a gravel walk, for instance, as on an old board lying across the walk.

There is needed in frost experimentation, in order to properly explain such questions as the one proposed, systematic records of temperature by sensitive resistance thermometers at different heights and on different surfaces. Also there is needed, just as much as the temperatures, records of the actual amounts of water vapor present, and these possibly could be obtained by the so-called saturation deficit recorders.

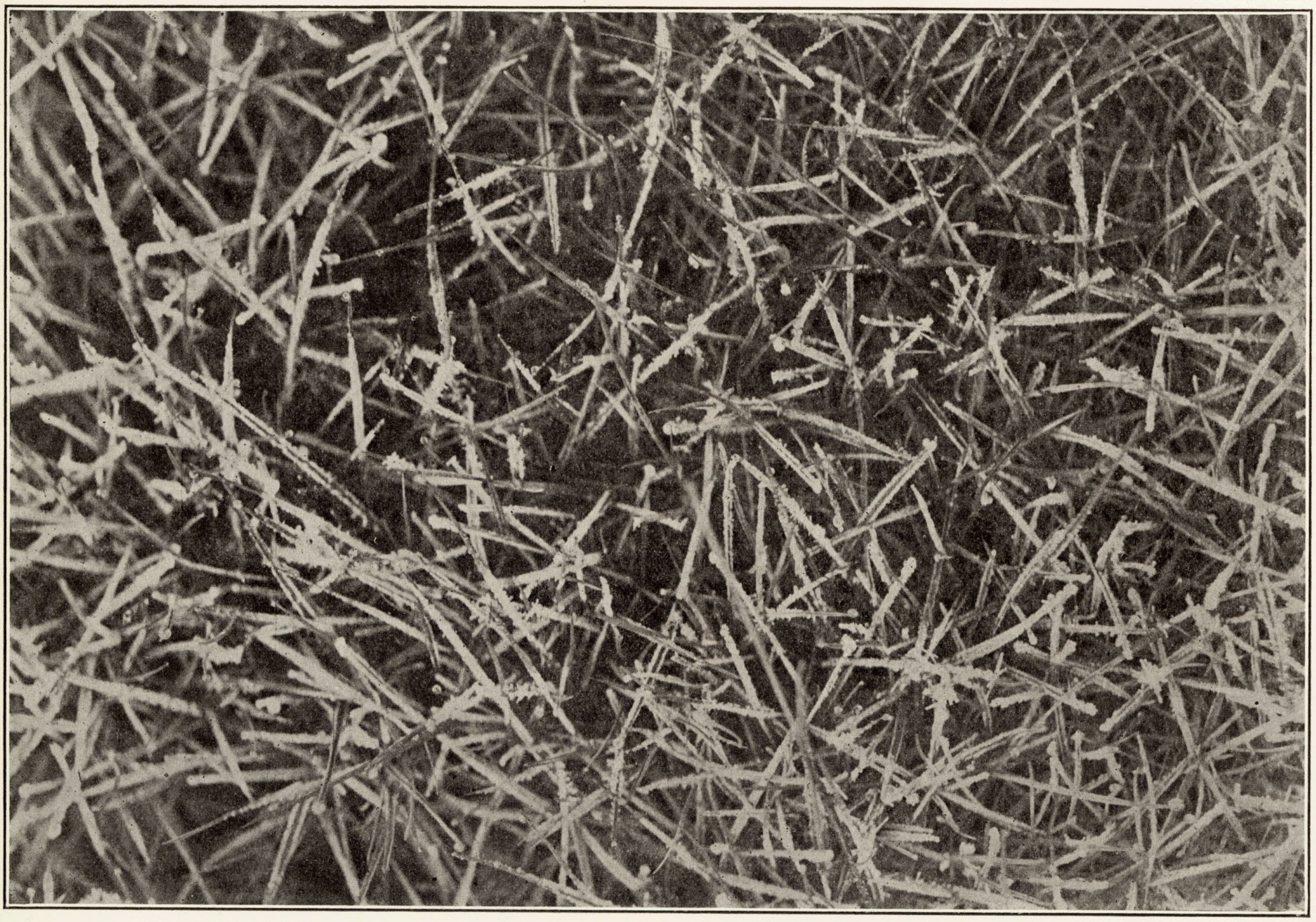
In the accompanying photographs, made by Mr. O. H. Packer, who has cheerfully given his time and assistance in the frost experiments carried on at San Francisco, it can be seen that the frost crystals apparently form only on the upper or outermost blades of grass. Underneath the top grass frost does not form. It is also apparent that frost building appears to be more energetic at the edge of a leaf than elsewhere. Tips of grass blades seem to show both dew and frost in much greater quantity than elsewhere.

FROST ON LEAVES.



DISTRIBUTION OF FROST CRYSTALS ON LEAF.

(Photographs by O. H. Packer.)



Frost on Grass at San Francisco, Cal.

(Photograph by O. H. Packer.)